

ANATOMICAL VARIANTS OF TYMPANIC COMPARTMENTS AND THEIR AERATION PATHWAYS INVOLVED IN THE PATHOGENESIS OF MIDDLE EAR INFLAMMATORY DISEASE

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Abstract

Aim: The aim of this article is to review the anatomy of middle ear compartments and folds and to demonstrate through anatomical evidence their presence at birth. Additionally, their role in the obstructions of middle ear ventilatory pathway is highlighted.

Methods: Ninety-eight adult temporal bones, with no history of auricular disease and fifteen newborn temporal bones were studied by micro dissection. Documentation was done by color photography using the operation microscope

Results: Our micro-dissections have showed that mucosal folds from the middle ear are steadily present since birth, given that they were found in all newborn temporal bones. The mucosal folds in our normal adult material, showed some variations including membrane defects but they were constantly present. Our micro dissections showed that the epitympanic diaphragm consisted, in addition to malleal ligamental folds and ossicles, of only two constantly present folds: the tensor tympani fold and the incudomalleal fold. When the tensor fold is complete the only ventilation pathway to the anterior epitympanic space is through the isthmus, whereas its absence creates an efficient additional aeration route from the Eustachian tube to the epitympanum.

Conclusions: The goal of surgery in the chronic pathology of the middle ear should be restoration of normal ventilation of the attical-mastoid area. This is possible by removing the tensor fold and restoring the functionality of the isthmus tympani.

Keywords: middle ear, mucosal folds, ventilation pathways, inflammatory process

Introduction

Chronic suppurative otitis media (CSOM) is a chronic inflammation of the middle ear and mastoid mucosa in which the tympanic membrane is not intact (perforation or tympanostomy tube) and discharge (otorrhea) is present [1]. The pathogenesis of CSOM is multifactorial: environmental versus genetically determined factors as well as anatomical and functional characteristics of the Eustachian tube are involved [2]. The factors that allow acute infections within the middle ear and mastoid to develop into chronic infections are unclear [3]. One of the contributing factors refers to the presence of anatomic blockages of the middle ear ventilation trajectories [4]. Aeration of the middle ear, antrum, and mastoid depends on the free movement of gases from the Eustachian tube into the mastoid air cells. Early studies showed that the middle ear is separated from the antrum not only by the ossicles, but also by mucosal folds [5]. This

arrangement creates an interattico-diaphragm with only one constant opening (Fig. 1). Edema and inflammation with granulation tissue may block these communicating openings, preventing drainage of the antrum and mastoid. Chronic obstruction of the attic and antrum with infection leads to "irreversible" inflammatory changes in the mucosa and bone of the middle ear cleft, with the appearance of CSOM [1]. There is a lot of controversy in literature regarding the origin of the middle ear folds and their contribution to the partition of the middle ear spaces [6].

The aim of this article is to review the anatomy of middle ear compartments and folds and to demonstrate through anatomical evidence their presence at birth. Additionally, their role in obstructions of middle ear ventilatory pathway is highlighted.

Materials and Methods

Ninety-eight adult temporal bones, with no history of auricular disease and fifteen newborn temporal bones were studied by micro dissection. All temporal bones had been harvested during autopsy and were preserved in a deep

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freezer and thawed in temperate water immediately before processing. Documentation was done by color photography using the operation microscope. For the adult temporal bones we used the following order of dissection. Transcanal approach: the temporal bone was fixed into the usual surgical position for tympanoplasty. A transverse incision in the ear canal skin was made at 6 mm lateral to the annulus. The tympanomeatal flap was elevated and transposed toward the front, up to the malleus handle. The Shrapnell's membrane was shifted downwards and Prussak's space was observed and analyzed regarding its ventilation routes. The superior approach via the middle fossa floor was performed by drilling the attical and adital tegmen, after a classical mastoidectomy. The presence of any folds from the posterior epitympanum was noted, and so were the position of transverse crest and the insertion of the tensor fold. The anterior approach was made, by cutting the temporal bone block frontally, allowing observation of the middle ear and supratubal recess from the protympanum. In some of the pieces we made a frontal cut at 2 mm from tympanic ring to obtain a medial view of the anterior and posterior pouches von Tröltzsch. For a better view of the inter-attico-tympanic diaphragm we also used inferior approach, performing a transverse cut in the hypotympanum, which granted us the lower inspection. For the newborn temporal bones it was not necessary to cut the pieces, they could be disarticulated due to incomplete fusion of their bone suture components.

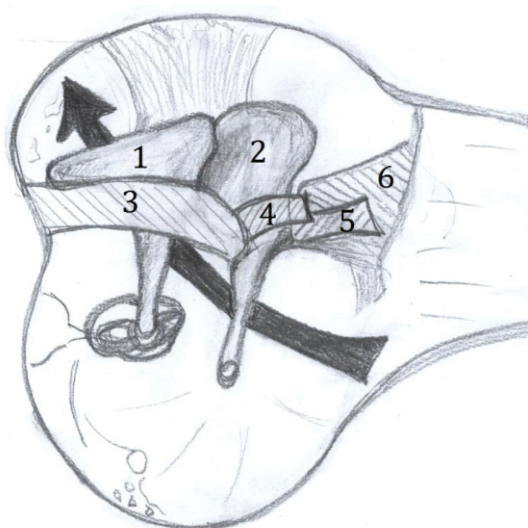


Figure 1. The interattico-diaphragm: 1. Incus. 2. Malleus. 3. Lateral incudomalleal fold. 4. Lateral malleal ligamental fold. 5. Anterior malleal fold. 6. Tensor tympani fold Isthmus tympani (black arrow).

The study had the approval of the local Ethical Committee from our institution. The study was conducted according to the Declaration of Helsinki on biomedical research involving human subjects.

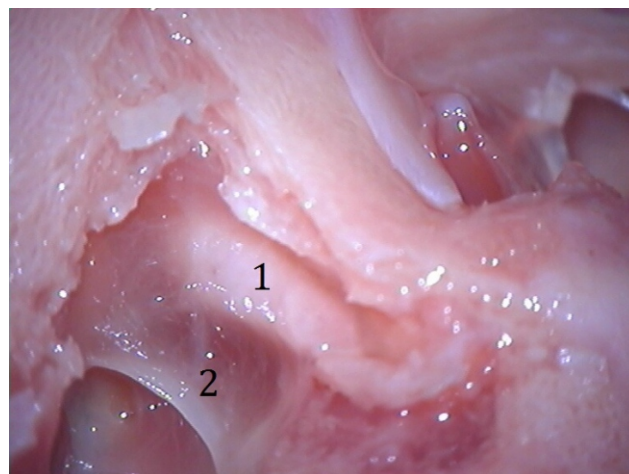


Figure 2. New-born temporal bone. Right ear. Superior view of the tympanic cavity: 1. Incus. 2. Complete mucosal folds blocking the communications between epitympanum and mesotympanum.

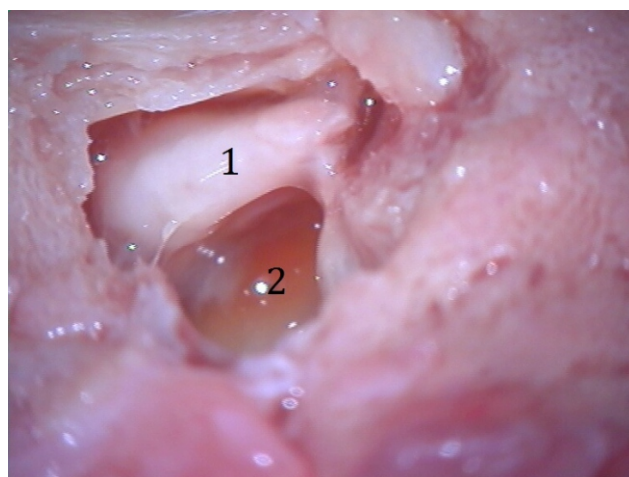


Figure 3. New-born temporal bone. Right ear. Superior view of the tympanic cavity: 1. Incus. 2. Amnion fluid cellular

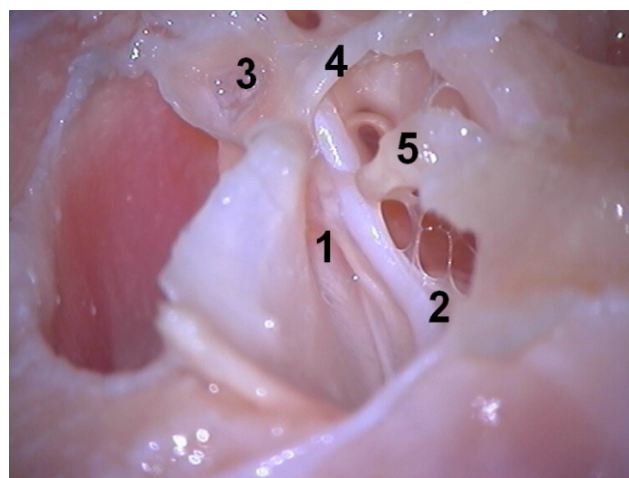


Figure 4. Adult temporal bone. Right ear. Inferior view of posterior pouches von Tröltzsch: 1. Posterior malleal fold. 2. Incomplete chordal fold. 3. Anterior malleal fold. 4. The tensor tympani tendon. 5. Stapes

Results

Our study showed the presence of the mucosal folds in all adult and newborn temporal bone. In the newborn temporal bone the folds were much better represented than in the adult one (Fig. 2). In two newborn temporal bones in the middle ear there was an influx of amnion fluid cellular content, blocking all aerated spaces of the middle ear (Fig. 3). The microdissections revealed the presence of the following folds in the middle ear:

The anterior ligamental malleal fold- was situated in the anterior portion of the epitympanic diaphragm taking part in the formation of the superior wall of the anterior pouch von Tröltsch, along with the long process of the malleus, the anterior malleal ligament, the chorda tympani nerve and the anterior tympanic artery. In our study this fold has proven to be constantly present in all adult and newborn pieces (Fig. 4).

The posterior malleal fold and chordal fold

The posterior malleal ligamental fold originates from the posterior portion of the malleus neck and the upper third of the malleus handle and is inserted posteriorly into the posterior tympanic spine. The posterior malleal ligamental fold was constantly present in all adult and newborn pieces. The chorda tympani fold was situated medially to the posterior malleal ligamental fold, encompassing the chorda tympani nerve. In a number of 71 adult bones (56%), the chorda tympani fold was united with the posterior malleal fold and in a number of 16 bones (30%) there was a space between the two folds. In a number of 11 bones (14%) the chordal fold was completely formed its insertion being at the posterior tympanic wall. In these cases the chordal fold had a very strategic position blocking the communication between the epitympanum and the mesotympanum in the posterior part of the tympanic cavity. The chordal fold was completely formed in a number of 10 newborn temporal bones (Fig. 4).

The lateral malleal fold was always present forming the superior wall of the Prussak's space.

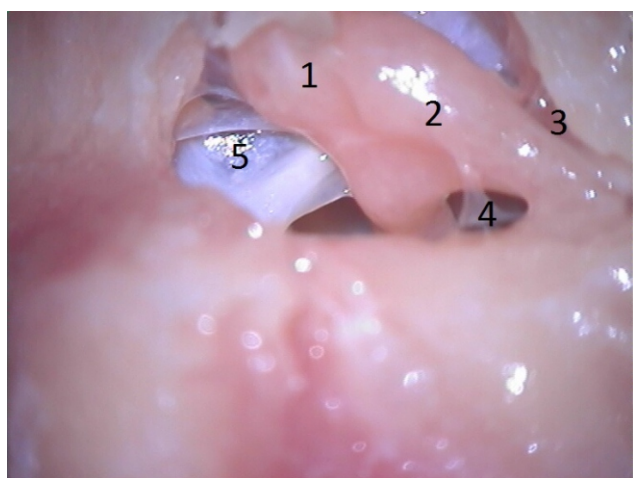


Figure 5. Superior view of the tympanic cavity: 1. Malleus. 2. Incus. 3. The lateral incudo malleolar. 4. Posterior incudal fold. 5. Tensor fold.

The lateral incudomalleal fold forms the roof of the lower lateral attic. In the posterior part the fold insertion it was at the incudis fossa, short process of the incus, and the lateral attic wall, but in the anterior part its insertion was variable. In all the pieces the lateral incudomalleal fold was located at the higher level than lateral and anterior malleal ligamental folds. In 56 pieces (57%) the lateral incudomalleal fold was complete and in 10 pieces of these (10%), its insertion was superiorly oblique. The lateral incudomalleal fold was partially formed in 42 pieces (43%) (Fig. 5).

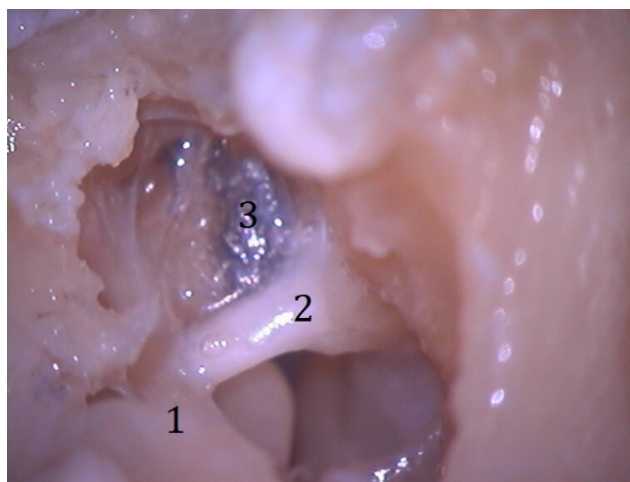


Figure 6. View of the tympanic cavity from the Eustachian tube. 1. Malleus handle. 2. Tensor tympani tendon. 3. Complete tensor fold.

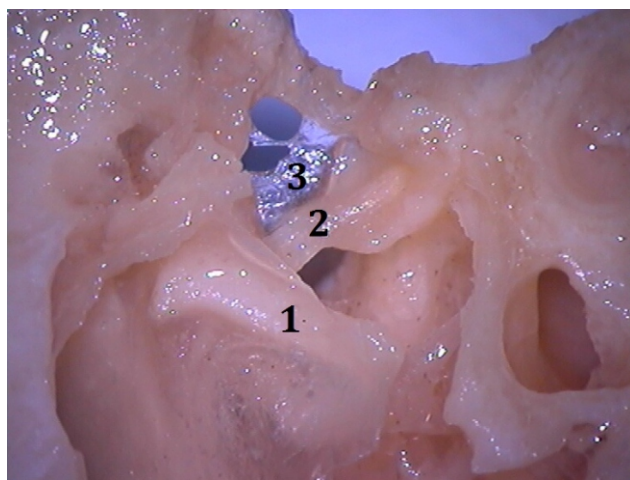


Figure 7. View of the tympanic cavity from the Eustachian tube. 1. Malleus handle. 2. Tensor tympani tendon. 3. Incomplete tensor fold.

The tensor fold

The tensor fold starts from the tensor tendon upwards and inserts to the attical tegmen (Fig. 5).

It may have a great variation in trajectory and dimension. The tensor fold was present in all temporal bones, completely formed in 65% of pieces and in 35% of them showed a central defect. The insertion of the fold was anterior to the transverse crest (a bone septum that starts

from the anterior tympanic spine and crosses the tegmen transversely 1-2 mm in front of the malleus head.) in 85% of pieces and in 15% of pieces at the transverse crest level (Fig. 6, Fig. 7).

Other folds from the middle ear

The medial incudal fold connects the short and long processes of the incus with the stapes. In our dissectional study we did not constantly find it, but it was present in 11% of temporal bones. When this fold was present, its insertion was found to be at the medial wall of the attic. Interossicular fold connects the long process of the incus with the handle of the malleus. In our dissection it was present in 13% of pieces.

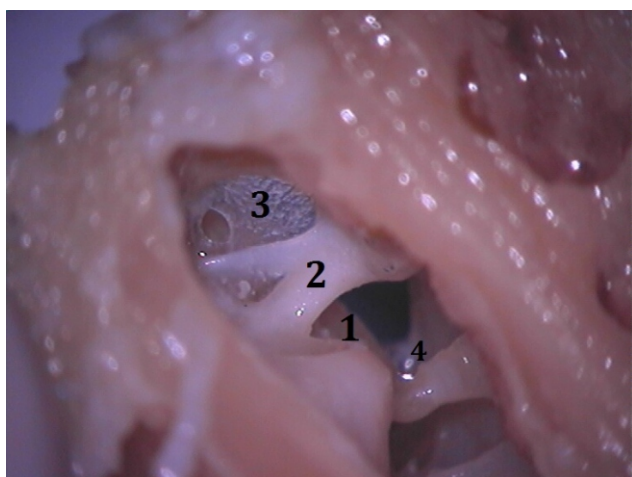


Figure 8. Inferior view of the tympanic cavity 1.Malleus handle. 2.Tensor tympani tendon. 3.Incomplete tensor fold. 4.Medial ossicular folds.

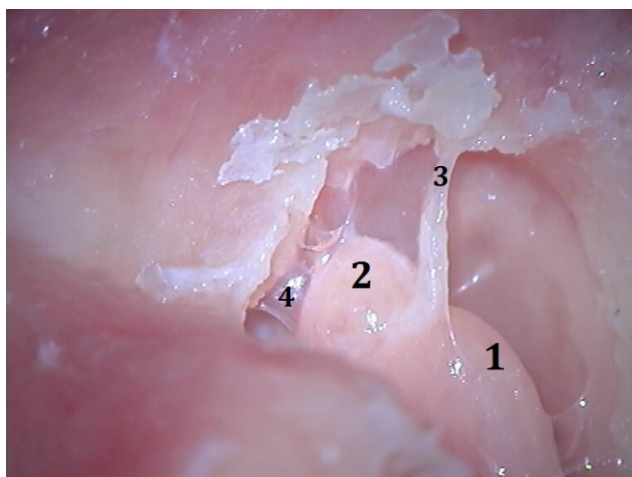


Figure 9. Superior view of the tympanic cavity. 1. Incus. 2. Malleus. 3,4. Superior folds in the anterior part of the epitympanum.

Stapedial folds are located between the incudostapedial articulation and the internal wall of mesotympanum and the obturator fold between the cruras of the stapes. These folds were found only in 18% and 9% of temporal bones. Posterior incudal fold emerges from posterior incudal ligament and

inserts onto the medial attic wall. In our temporal bone series this fold was present in 15% of pieces. In 18% of pieces we found some very thin folds in the anterior part of the attic above tensor tympani fold (Fig. 8). Superior malleal fold that accompanies superior malleal ligament was present in 78% of pieces (Fig. 9).

Discussion

Regarding the presence and the origin of the mucosal fold in the middle ear there is a lot of controversy in the literature, some authors considered them a result from an earlier inflammation [6].

Our microdissections showed that they are steadily present since birth, as they were found in all new-born temporal babies, not subject to any infection during their life. Their consistency was thicker than in the adult bone. The mucosal folds in our normal adult material, showed some variations including membrane defects but they were constantly present. The importance of the mucosal folds presence in the middle ear lies in the fact that they take part in the composition of the epitympanic diaphragm, which divides the middle ear cleft into two separate compartments: epitympanum (superior unit) and mesotympanum (inferior unit) [7]. This barrier is not impenetrable. There is a small permanent opening: the anterior tympanic isthmus, which is situated between the tensor tympani tendon and the stapes. Different authors studied the anatomy of the epitympanic compartments: recently Palva et al. [8] described the anatomy of the epitympanic diaphragm studying ventilation pathways of the epitympanum. Palva et al. [8] observed that the aeration pathway from the Eustachian tube leads directly to the mesotympanic and hypotympanic spaces, whereas the epitympanum is away from the direct air stream and is only aerated through the tympanic isthmus. In his work based on fresh temporal bone dissections, Aimi et al. [9] described the tympanic isthmus as a narrow passage between the tubotympanic cavity and the atticomastoid air space. He observed that obstruction of the tympanic isthmus was common in various types of middle ear disease and caused significant air-diffusion disturbance within the temporal bone pneumatic system. Aimi et al. [9] also noted that the factors that caused an obstruction of the tympanic isthmus were mucosal fold variations, inflammatory webs and exudate, retracted tympanic membrane, diseased attic mucosa and cholesteatoma. These findings were sustained also by Marchioni et al. in several articles [10,11,12] who endoscopically studied the presence of anatomic blockages of the middle ear ventilation trajectories. Our microdissections showed that the epitympanic diaphragm consisted, in addition to malleal ligamental folds and ossicles, of only two constantly present folds. These were the lateral incudomalleal fold, separating the epitympanum and mesotympanum in the posterior part of the tympanic cavity and the tensor fold, separating the epitympanum from the mesotympanum in the anterior part of the tympanic

cavity. Other than the incudomalleal and tensor folds, and tiny remnants of other fetal folds, were considered to derive, as a rule, from inflammation [13]. Membrane defects in these two main folds may already appear at birth or may develop later. The tensor tendon fold has a very strategic position and importance in the anatomy of the middle ear spaces. When the tensor fold is complete the only ventilation pathway to the anterior epitympanic space is through the isthmus, whereas its absence creates an efficient additional aeration route from the Eustachian tube to the epitympanum.

We believe that post inflammatory folds develop especially in narrow niches, e.g. around the stapes, and their final thickness depends upon the stage and mode of exudate organization. The longer an inflammation is active, with poor drainage and stagnating exudate in the narrow spaces, the greater will be the development of new folds and the greater a further reduction of the available aeration routes. We shall return later to the large spectrum of postinflammatory pathological and irreversible changes in temporal bones. The mode of their origin, as well as the question of their prevention, is one of the major ill-understood concerns of otology nowadays.

Conclusions

Based on our study we conclude that the middle ear folds are constantly present at birth and their presence can block aeration pathways to epitympanum, causing otological inflammatory pathology. Intraoperative evaluation of the middle ear anatomy during surgery for chronic otitis media, allows restoration of normal ventilation of the attical-mastoid area by removing the tensor fold and restoring the functionality of the isthmus tympani.

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